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The pyrolysis simulation of five biomass species by hemi-cellulose, cellulose and lignin based on thermogravimetric curves

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ABSTRACT

The thermal behavior of five biomass species was investigated using a thermogravimetric analyzer (TGA). The investigation showed that the hemi-cellulose in fruit vegetable biomass differed from that in wood biomass. The cellulose in different materials except Chinese cabbage presented coincident properties while different lignin varied greatly because of various monomers. The thermogravimetric curve overlap ratio was applied to evaluate the simulation of biomass by hemi-cellulose, cellulose and lignin. The results indicated that biomass pyrolysis characteristics could be well simulated by its components and the results from the overlap ratio were compared with the content derived from chemical separation. The temperature was programmed to divide each phase of biomass pyrolysis to investigate further components ratio in biomass mass loss process. The results suggested that fruit vegetable biomass contained more hemi-cellulose and less lignin than wood biomass, and poplar wood contained the largest amount of cellulose.

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1. Introduction

With the exhaustion of fossil fuels, biomass, as a clean and renewable source of energy, has gained worldwide concern. As a renewable green energy resource, biomass is getting much attention. Lignocellulosic biomass represents a renewable and largely untapped source of raw feedstock for conversion into liquid and gas fuels, thermochemical products and other energy-related end products [1].

The thermal utilization methods of biomass include direct combustion, pyrolysis, and gasification. The biomass combustion process can be schematically described as Fig. 1 [2]. The importance of the pyrolytic characteristics of a given biomass relies not only on the pyrolytic products but also on the fact that pyrolysis is the first chemical step in gasification or combustion [3].

Besides a small amount of pectin, protein alkaloid, etc., biomass mainly consists of hemi-cellulose, cellulose and lignin. The ratio of the three components in a biomass differs with the source of the biomass [2]. These three substances have significantly different thermal stabilities [2,4–11]. TGA is one of the most common techniques used to investigate the thermal behavior of small fuel samples, with no limitations in heat and mass transfer at low heating rates [5,7–17]. Obtained results can be used to determine reactivity, which includes pyrolysis rate (mass loss per time unit) and mass loss kinetics, of the fuels.

Many researchers tried to simulate biomass pyrolysis properties from hemi-cellulose, cellulose and lignin using different methods [2,4–6]. A kinetic model of independent parallel reactions was applied to the experimental results of TGA pyrolysis using a three-step devolatilization mechanism [2]. The additivity law was adopted to predict the product components of biomass pyrolysis based on the content of hemicelluloses, cellulose, and lignin [4]. The kinetics of the pyrolysis of lignocellulosic materials was applied to suggest that the rate of pyrolysis of one biomass could be represented by the sum of the corresponding rates of the main biomass components [5]. However, in former research, the kinetics models and parameters were introduced and suggested when the researchers tried to simulate and predict the biomass pyrolysis by their main components. Because of different suggested kinetics models, the simulated pyrolysis of biomass was often overestimated or underestimated.

The aim of this work was to investigate the mechanism of biomass pyrolysis based on its component substances. Here, to avoid overestimation or underestimation due to different kinetics models, thermogravimetric (TG) curve of the biomass pyrolysis is simulated directly by those of its main components. The TG curve overlap ratio was proposed for the first time to evaluate the simulation of biomass pyrolysis process from hemi-cellulose, cellulose and lignin based on the linear temperature experiments. Furthermore, the fractionated pyrolysis experiments were designed, so that the pyrolysis progress of different

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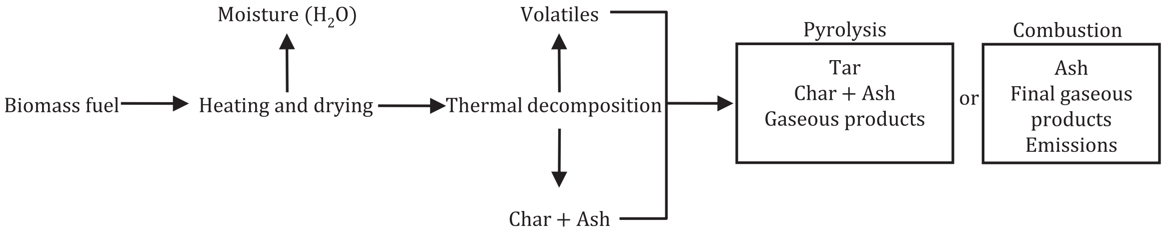

Fig. 1. Schematic illustration of the biomass combustion process.

compositions could be separated to explore the mechanism of biomass pyrolysis.

2. Material and methods

2.1. Materials

2.1.1. Biomass samples

Samples of biomass included poplar wood (PW), poplar leaf (PL), chinar leaf (CL), Chinese cabbage (CC) and orange peel (OP). The first three represented wood biomass and the last two represented fruit vegetable biomass. The proximate and ultimate analysis of the samples was shown in Table 1. Table 1 showed that the proximate and ultimate analysis of different biomass were similar. The ash content of poplar leaf was higher than the result of [18], which was due to some dust on the collected leaf. In the TGA experiments, biomass was ground to fine powder by a GJ-1 sealed type chemical examination system type grinder and then sieved to less than 250 μm, which is small enough to prevent heat transfer effect in isothermal and dynamic experiments [19]. About 25 mg biomass was experimented as the dry basis.

2.1.2. Samples of hemi-cellulose, cellulose and lignin

As biomass consists of hemi-cellulose, cellulose and lignin, 1 kind of hemi-cellulose, 4 kinds of cellulose and 4 kinds of lignin were experimented by TGA to explore the relationship of biomass and its components. Xylan was a common kind of hemi-cellulose [20] with molecular mass of approximately 30,000 (200 xylopyranose units) and the chemical formula was $(C_5H_8O_4)_n$. The xylan in this research was bought from Corporation Service Company (CSC), with the purity more than 85%. The pure cellulose samples included filter paper, absorbent cotton, absorbent cotton gauze as well as microcrystalline cellulose and all of these contained cellulose more than 99%. The filter paper was bought from Hangzhou Special Paper Industry Co., Ltd. and produced based on ASTME 832-81. The microcrystalline cellulose was bought from Beijing Jingqiu Chemical Co., Ltd. In commercial pulping and bleaching processes, acids, alkalis, organic solvents or biological agents are used for degradation and dissolution of lignin, thereby enabling separation of the cellulose fibers from the lignin [21]. Industrial highly pure lignin (from Changzhou Peaks Chemical Co., Ltd., purity >90%) in this research was produced using alkali to dissolve lignin, followed by the recovery of lignin from the solution. Sodium ligninsulfonate, alkali lignin and lignin (dealkaline) extracted directly from biomass (from Tokyo Chemical Industry Co., Ltd.) were also experimented. All the pure substances were also powered to less than 250 μm. Approximately 25 mg of each substance was experimented in TGA as the dry basis.

2.2. Experimental apparatus

The TGA was NETZSCH STA 409C/3/F and pure N_2 with a flow rate of 100 ml/min was used. In the linear temperature experiments, temperature rose from 50 °C to 1000 °C at a heating rate of 10 K/min. The fractionated pyrolysis experiments included isothermal process (standard temperature) and non-isothermal process (standard heating rate). The heating temperature was always 10 K/min and the thermal treatment was done at 150, 250, 300, 500 and 1000 °C for 20, 40, 50, 30 and 20 min, respectively. The temperature might overshoot 5–10 °C at the beginning of isothermal process. Repeated experiments showed that TG curves had good reproducibility.

3. Results and discussion

3.1. Pyrolysis of biomass

The TG and derivative thermogravimetric (DTG) curves for biomass pyrolysis at heating rate of 10 K/min were shown in Figs. 2 and 3, respectively. The pyrolysis of biomass presented 3 stages and mass loss processes are summarized in Table 2.

As shown in Figs. 2 and 3, poplar wood and poplar leaf as different parts of the same kind of biomass presented a similar mass loss process. The residual mass of poplar leaf was larger than poplar wood in accord with the analysis in Table 1. Poplar leaf and chinar leaf as the same part of different biomass had similar mass lost process. The first mass loss peak and the second peak of chinar leaf were separate, which differed from those of poplar leaf, whose first peak was close to the second peak. The third stage for fruit vegetable biomass started from 345 to 365 °C and lasted to 1000 °C with no obvious peak. While for wood biomass, the third stage started from 500 °C and ended at 1000 °C with a peak at about 700 °C, which distinguished it from fruit vegetable biomass.

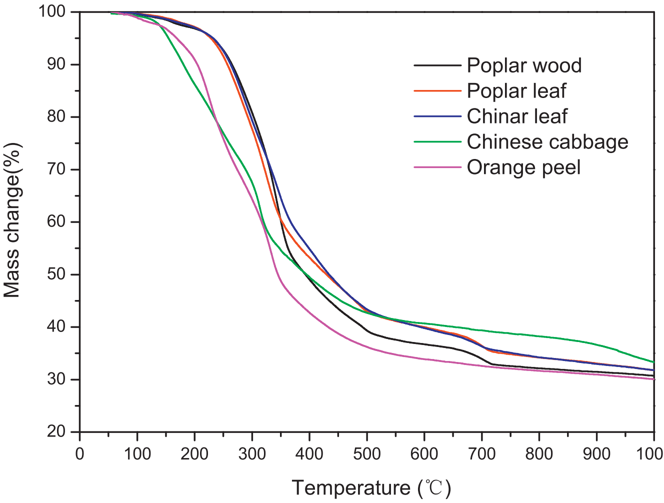

Fig. 2. TG curves for biomass fuels from pyrolysis at a heating rate of 10 K/min.

Table 1
Proximate and ultimate analysis of the biomass.

Biomass	Proximate analysis				Elemental analysis				HHV^d (MJ/kg)
	A^d%	V^d%	FC^d%	S^{t,d}%	C^d%	H^d%	N^d%	O^d%	
Poplar wood	7.54	73.85	18.61	0.20	47.49	5.45	1.41	37.91	18.50
Poplar leaf	15.69	68.74	15.57	0.26	41.77	4.42	1.11	36.75	16.85
Chinar leaf	9.23	69.74	21.03	0.30	48.06	4.43	0.92	37.06	19.12
Chinese cabbage	9.91	67.60	22.49	0.55	42.78	5.30	3.70	37.76	16.99
Orange peel	2.91	76.49	20.6	0.18	47.32	5.75	1.39	42.45	18.47

A: ash content; V: volatile matter content; FC: fixed carbon content; HHV: higher heating value; d: dry basis; t: total.

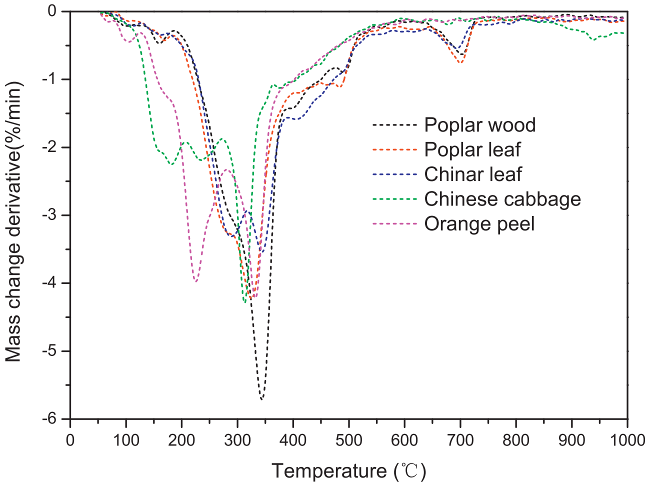

Fig. 3. DTG curves for biomass fuels from pyrolysis at a heating rate of 10 K/min.

3.2. Pyrolysis of hemi-cellulose, cellulose and lignin

3.2.1. Pyrolysis of hemi-cellulose

The TG and DTG curves of hemi-cellulose (xylan) were shown in Fig. 4. The mass loss occurred between 210 and 310 °C and there were two DTG peaks at 246 °C and 274 °C, respectively. Hemi-cellulose was consisted of various saccharides (xylose, mannose, glucose, galactose, etc.) [7]. The xylan was used as hemi-cellulose sample in this experiment and might contain two different kinds of saccharides.

Table 2
Mass loss process of biomass fuels.

Biomass fuel	Temperature range (°C)	DTG peak temperature (°C)	Mass loss (%)
Poplar wood	190–360	280.0 344.6	41.16
	360–510	492.7	17.12
	510–1000	703.1	8.03
Poplar leaf	185–360	278.0 326.3	39.14
	360–500	484.9	15.56
	500–1000	702.8	11.27
Chinar leaf	210–360	289.6 345.1	36.03
	360–500	–	17.12
	500–1000	697.6	11.61
Chinese cabbage	205–285	234.8	14.67
	285–365	313.4	17.67
	365–1000	–	19.72
Orange peel	185–279	226.0	24.13
	279–345	333.0	18.96
	345–1000	–	19.97

The first DTG peak of biomass was regarded as the pyrolysis of hemi-cellulose [2,8,9]. Table 3 showed the mass loss process of hemi-cellulose. Comparing the first peak of biomass in Table 2 and the two peaks of hemi-cellulose, the DTG peaks of fruit vegetable biomass approximated the first peak of hemi-cellulose, while the DTG peaks of wood biomass were close to the second peak of hemi-cellulose. It indicated that the hemi-cellulose in fruit vegetable biomass differed from the hemi-cellulose in wood biomass.

3.2.2. Pyrolysis of cellulose

As cellulose is the main component in wood and crops, its thermal degradation has been the subject of extensive research [22–24]. The pure cellulose samples of this research included filter paper (FP), absorbent cotton (AC), absorbent cotton gauze (ACG) and microcrystalline cellulose (MC). As shown in Figs. 5 and 6, different cellulose presented similar mass loss properties. The pure cellulose had one single mass loss process, which started from 300 to 315 °C, had a steep peak at 342–354 °C and ended at 360–380 °C.

The second DTG peak of biomass was regarded as the pyrolysis of cellulose [2,8,9]. Comparing the second peak of biomass in Table 2 and the peak of cellulose shown in Table 3, the peak temperature of biomass came close to the peak of cellulose located at 313–354 °C. The cellulose in different materials presented coincident properties, because the cellulose molecule was a very long polymer of glucose units without any branches, and it was crystalline [2]. However, the peak temperature of Chinese cabbage presented lower than that of other materials, and it needed further study.

3.2.3. Pyrolysis of lignin

Sodium ligninsulfonate, industrial high purity lignin, alkali lignin and lignin (dealkaline) were experimented in TGA. The TG and DTG curves in Figs. 7 and 8 showed that the pyrolysis properties of different lignin varied greatly. That was because lignin was

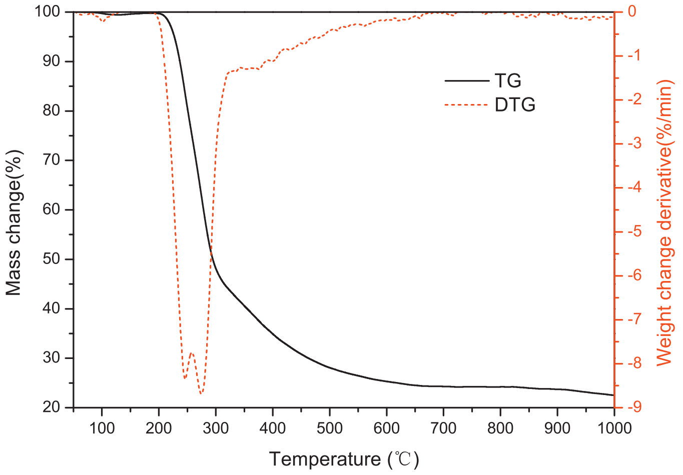

Fig. 4. TG and DTG curves for hemi-cellulose from pyrolysis at a heating rate of 10 K/min.

Table 3
Mass loss process of hemi-cellulose, cellulose and lignin.

Materials	Samples	Temperature range (°C)	DTG peak temperature (°C)	Mass loss (%)
Hemi-cellulose	Xylan	210–258	246.3	24.21
		258–300	274.7	27.02
Cellulose	Microcrystalline cellulose	300–360	341.9	74.17
	Filter paper	310–370	341.8	85.14
	Absorbent cotton	315–380	353.7	76.87
	Absorbent cotton gauze	310–375	352.8	79.75
Lignin	Sodium ligninsulfonate	149–1000	187.8, 248.2, 323.1, 700.9	61.23
	Industrial high purity lignin	153–1000	363.7	61.98
	Alkali lignin	151–1000	327.5	43.10
	Lignin (dealkaline)	151–1000	347.1, 748.5	48.53

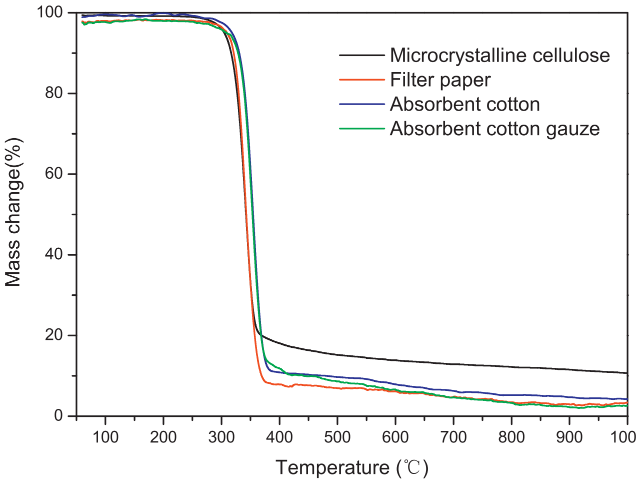

Fig. 5. TG curves for different kinds of cellulose from pyrolysis at a heating rate of 10 K/min.

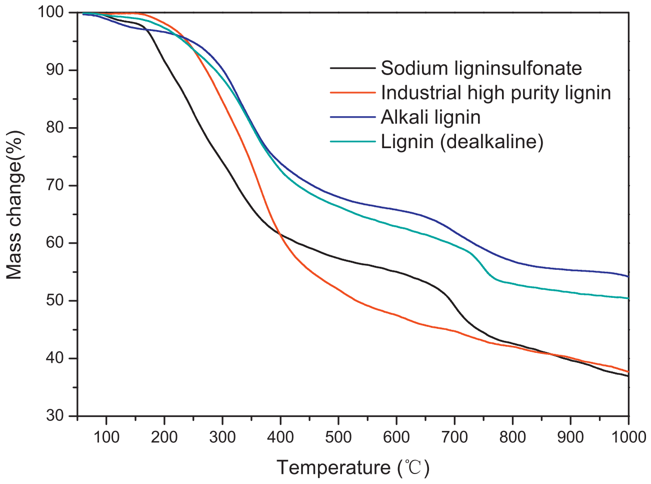

Fig. 7. TG curves for different kinds of lignin from pyrolysis at a heating rate of 10 K/min.

formed from three highly cross-linked phenylpropane units of p-coumaryl alcohol, coniferyl alcohol and sinapyl alcohol [25]. Unlike cellulose, lignin was a highly cross-linked polyphenolic aromatic polymer having no ordered repeating units [26].

In comparison to the sharper DTG peaks of cellulose and hemi-cellulose, lignin had wide and flat DTG peaks. Lignin started to decompose at about the same temperature as hemicellulose and showed gradual mass loss until 1000 °C [2]. Table 3 indicated that lignin lost mass from 150 °C to 1000 °C and the peak temperatures varied from 187.8 °C to 748.5 °C, which was different from the reports in [17] because the heating rate in [17] was much higher (200 K/min).

The isolation method has an influential role in determining the nature and structure of lignin. Industrial high purity lignin, alkali lignin and lignin (dealkaline) were from alkali method and sodium ligninsulfonate was from sulfite process. Alkali method is relatively free from sulfur contamination while considerable amounts of sulfonate groups are incorporated into lignin during sulfite process [27]. However, the alkali in lignin will decompose to oxide

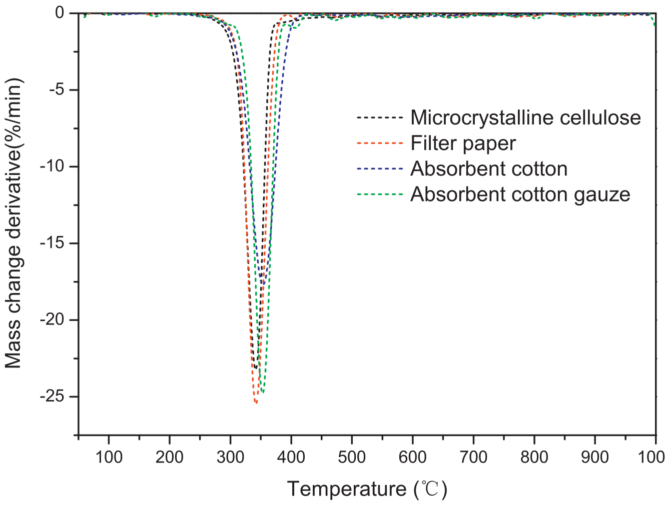

Fig. 6. DTG curves for different kinds of cellulose from pyrolysis at a heating rate of 10 K/min.

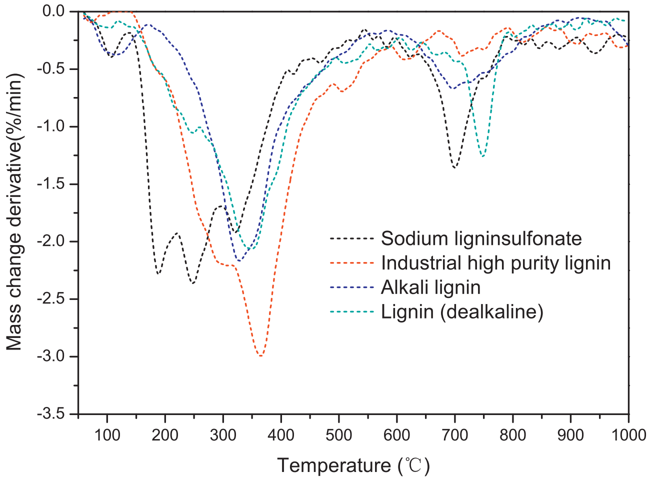

Fig. 8. DTG curves for different kinds of lignin from pyrolysis at a heating rate of 10 K/min.

during the heating process, which will disturb the TG curve of lignin. Therefore, lignin (dealkaline) is a better representative for thermal properties analysis. Meanwhile, during the treatment of isolation, the polymer is broken into smaller fragments [28], which means the lignin sample with higher thermal stability is more similar to the native lignin. In Table 3, lignin (dealkaline) has the best thermal stability with two peaks at 347.1 and 748.5 °C. Based on the above two reasons, lignin (dealkaline) was regarded as the best representative of lignin in this paper.

3.3. *The simulation of biomass pyrolysis by hemi-cellulose, cellulose and lignin based on overlap ratio*

In the actual biomass pyrolysis process, moisture, ash, and fixed carbon do not participate in chemical reactions and the moisture and ash content of the same material may vary from time to time. Therefore, the TG curves can be normalized with no moisture and ash, and those containing moisture and ash can be derived from proximate analysis result.

Here, m_0 denoted the relative mass before normalization (%), m_m denoted the mass of moisture (%), and m_r denoted the mass of ash and fixed carbon (%). The relative mass after normalization was denoted as follows:

$$m = \frac{m_0 - m_m - m_r}{1 - m_m - m_r} \times 100\% \tag{1}$$

Because the biomass pyrolysis mainly took place above 200 °C, the mass loss below 200 °C was regarded as the moisture content and the residual mass at 1000 °C was regarded as the ash and fixed carbon content.

Biomass mainly consists of hemi-cellulose, cellulose and lignin. From the results mentioned above, the properties of hemi-cellulose, cellulose and lignin in biomass were similar with the properties of the pure substances. Therefore, these three substances could be applied to simulate biomass.

The mass loss of biomass function could be denoted as $m(t)$. The relative mass m was the function of temperature t. After normalization, the initial m was 1 and the terminal m was 0. Here, m_1 denoted the hemi-cellulose mass, m_2 denoted the cellulose mass, and m_3 denoted the lignin mass. Eq. (2) could be derived according to mass conservation, where *i*, *j* and *k* denote the percentage of hemi-cellulose, cellulose and lignin, respectively.

$$m(t) = im_1(t) + jm_2(t) + km_3(t) \tag{2}$$

Eq. (3) could be derived according to substance conservation.

$$i + j + k = 1 \tag{3}$$

Supposing the interaction among m_1, m_2, m_3 could be neglected, the optimal i, j, k were obtained based on m, m_1, m_2, m_3.

According to the results mentioned above, xylan was used as the representative of hemicellulose, microcrystalline cellulose was used as the representative of cellulose and lignin (dealkaline) was used as the representative of lignin in the actual simulation.

To evaluate the similarity of two TG curves, the overlap ratio was introduced, which was defined in Eq. (4).

$$R = 1 - \frac{\text{area sandwiched by two curves}}{\text{total area}} = 1 - \frac{\int_{t_s}^{t_e} |\Delta m(t)| dt}{(t_e - t_s)(m_s - m_e)} \tag{4}$$

In Eq. (4), $|\Delta m(t)|$ denoted the absolute value of difference of two TG curves corresponding temperature, and t_s, t_e, m_s and m_e denoted start temperature, end temperature, start mass and end mass, respectively. The total area in Eq. (4) was defined as $(t_e - t_s)(m_s - m_e)$, which was actually constant for every case to make the overlap ratio a dimensionless number. After normalization, t_s and t_e were 200 °C and 1000 °C, respectively; m_s and m_e were 100% and 0%, respectively. According to the definition of R, $R = 0$ when one sample reacts completely at the start temperature and the other reacts completely at the end temperature, so the pyrolysis characteristics of these two samples have the greatest difference. $R = 1$ when two curves coincide, and $0 < R < 1$ in other cases.

Table 4
The simulated results of biomass by hemi-cellulose, cellulose and lignin.

	Hemi-cellulose (i)	Cellulose (j)	Lignin (k)	Overlap ratio
Poplar wood	0.26	0.50	0.24	0.9819
Poplar leaf	0.33	0.27	0.40	0.9843
Chinar leaf	0.26	0.30	0.44	0.9802
Chinese cabbage	0.46	0.08	0.46	0.9765
Orange peel	0.66	0.21	0.13	0.9888

N sets of data were exported from the TG curve and the TG overlap ratio was determined as follows. During calculation, N was taken as 16,000, which was big enough to reduce the error.

$$\begin{aligned} R &= 1 - \frac{(t_e - t_s)\lim_{N\to\infty}\left(\left(\sum_N |\Delta m(t)|\right)/N\right)}{(t_e - t_s)(m_s - m_e)} \\ &= 1 - \lim_{N\to\infty} \frac{\sum_N |\Delta m(t)|}{N} \end{aligned} \tag{5}$$

Taking the TG curve overlap ratio as the criteria, the simulated curve and the experimental curve when R reached the maximum were shown in Fig. 9.

As shown in Fig. 9 and Table 4, the biomass pyrolysis could be simulated well by hemi-cellulose, cellulose and lignin, and all the curve overlap ratios reached more than 0.9765. Karp and Shield [29] reported that poplar wood contained 28% hemicellulose, 48% cellulose and 24% lignin (dry ash free basis), which meant that the simulation results of poplar wood by the model in this paper agreed well with the components derived from chemical method. Yuan et al. [30] reported that the hemicellulose content of chinar leaves was 20–25%, the cellulose content was 45–50%, and the lignin content was 20–25%, which meant the model in this paper overestimated the lignin content and underestimated the cellulose content compared to chemical method. The structure of extracted lignin is expected to be slightly different from that of native lignin [27], and this model is depends on the choices of representatives of hemi-cellulose, cellulose and lignin. Better representatives of these three components should be tested in further study. The simulated results showed that Chinese cabbage contained only 8% cellulose and a large amount of lignin, which deviated from the true value in [31]. It could be concluded that the model was limited when cabbage only contained very small amount of fiber substances, as shown in [31]. Bicu et al. [32] reported that orange peel contained 52% pectin, 20% hemicellulose, 26% cellulose and 2% lignin. As shown in Table 4, part of the pectin was counted as hemicellulose and part of the pectin was counted as lignin.

3.4. *Fractionated pyrolysis*

The fractionated pyrolysis experiments were designed to separate the pyrolysis progress of different compositions in order to explore the mechanism of biomass pyrolysis. According to the experimental results of Table 2, the temperature program was designed. There were four isothermal progresses at 150 °C, 250 °C, 300 °C and 500 °C to separate the mass loss peaks. The isothermal progress at 150 °C was designed to make the bound water in biomass escape. The isothermal progress at 250 °C was designed to make hemi-cellulose decompose completely and cellulose did not react at this temperature. The isothermal progress at 300 °C

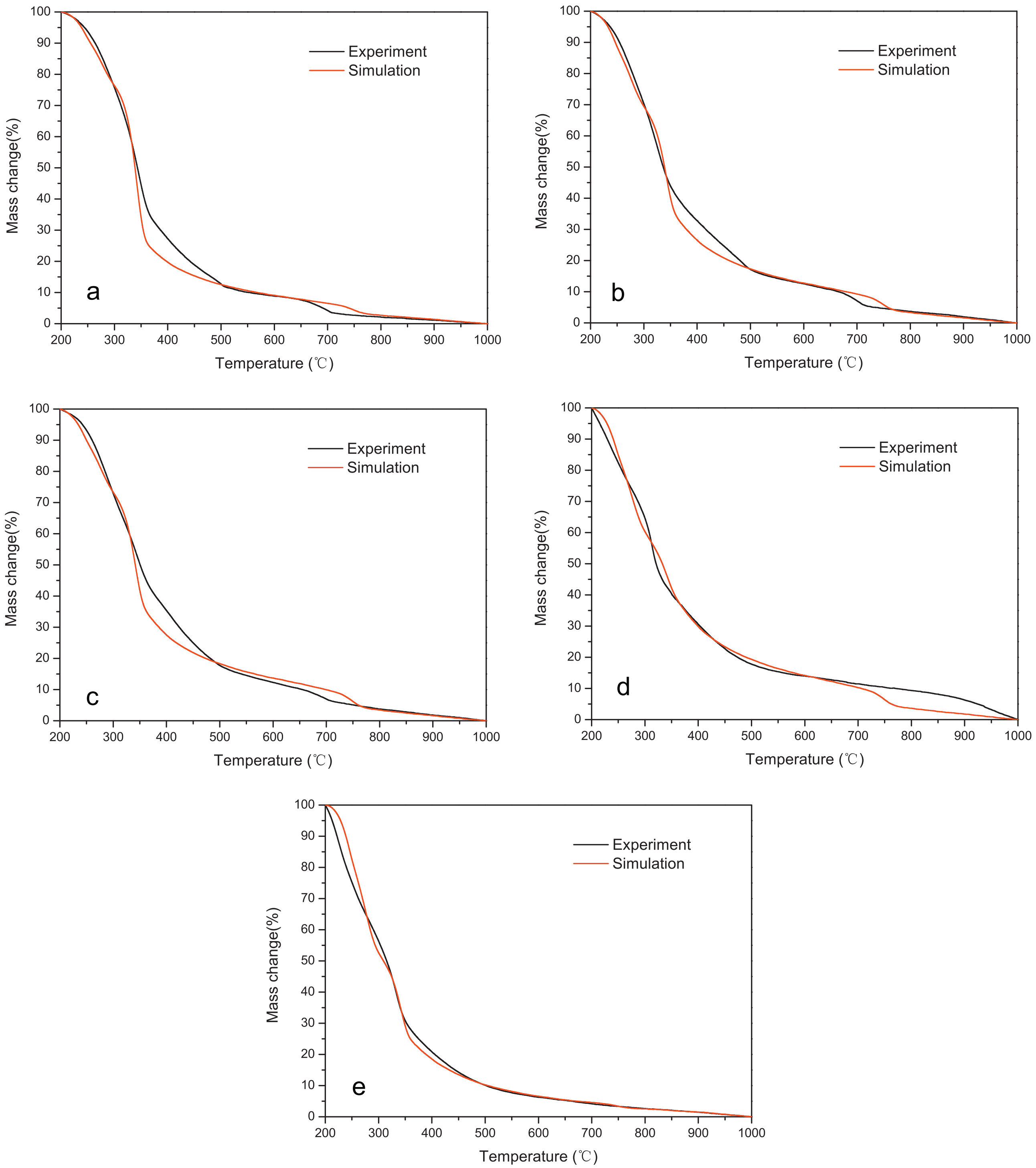

Fig. 9. The biomass pyrolysis curves contraction of simulated results by hemi-cellulose, cellulose and lignin and experimental results (a, poplar wood; b, poplar leaf; c, chinar leaf; d, Chinese cabbage; e, orange peel).

was designed to make cellulose pyrolysis completely. The process from 300 to 1000 was to make the rest of lignin decompose. The fractioned pyrolysis results of poplar wood, poplar leaf, chinar leaf, Chinese cabbage and orange peel were shown in Fig. 10 and Table 5.

Because the pyrolysis of lignin took place in a wide temperature range, it was difficult to distinguish the mass loss derived from lignin pyrolysis below 300 °C. In this paper it was supposed that the lignin in all biomass was lignin (dealkaline), whose fractionated pyrolysis was shown in Fig. 11 and Table 5. Then the mass loss derived from

Table 5
The mass loss of fractionated pyrolysis.

Biomass	Mass loss of different temperature ranges (%)		
	150–250 °C	250–300 °C	300–1000 °C
Poplar wood	16.50	24.65	30.26
Poplar leaf	17.98	18.17	28.27
Chinar leaf	16.88	17.43	33.42
Chinese cabbage	20.55	15.05	25.68
Orange peel	28.67	18.03	20.59
Lignin (dealkaline)	7.59	8.77	31.30

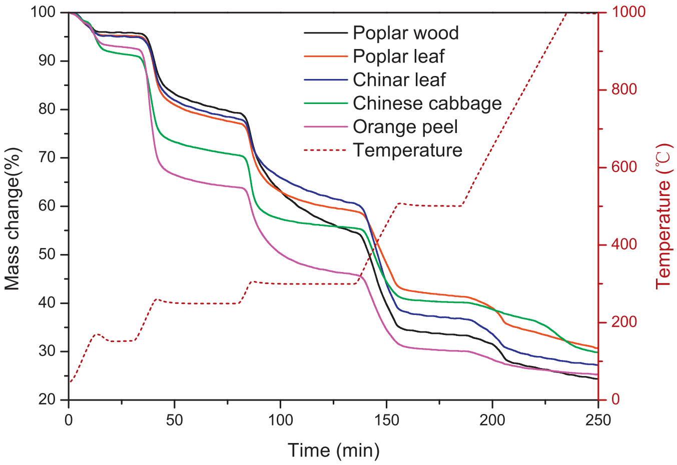

Fig. 10. Fractionated pyrolysis TG curves of biomass.

hemi-cellulose, cellulose and lignin could be calculated, respectively.

The mass loss of materials during 150–250 °C, 250–300 °C and 300–1000 °C was denoted by f_1, f_2 and f_3, respectively. Then the mass loss of f_1 was derived from hemi-cellulose and lignin; the mass loss of f_2 was derived from cellulose and lignin, and the mass loss of f_3 was derived from lignin alone. The percentage of lignin could be calculated from f_3, and the percentage of hemi-cellulose and cellulose could be calculated from f_1 and f_2, respectively, as shown in Eqs. (6), (7) and (8).

$$f_{\text{biomass, hemi-cellulose}} = \frac{f_{\text{biomass, 1}} - f_{\text{biomass, 3}} \cdot f_{\text{lignin, 1}}}{f_{\text{lignin, 3}}} \quad (6)$$

$$f_{\text{biomass, cellulose}} = \frac{f_{\text{biomass, 2}} - f_{\text{biomass, 3}} \cdot f_{\text{lignin, 2}}}{f_{\text{lignin, 3}}} \quad (7)$$

$$f_{\text{biomass, lignin}} = 1 - f_{\text{biomass, hemi-cellulose}} - f_{\text{biomass, cellulose}} \quad (8)$$

Table 6 showed the results calculated based on Eqs. (6)–(8). The results were the mass loss derived from three components, not exactly the content of three components. During the purification of lignin, the lignin molecules were broke into small pieces, so the lignin (dealkaline) used in this research had a poorer thermal stability than the lignin in biomass. For this reason, the mass loss derived from lignin shown in Table 6 was excessive and the results of hemi-cellulose and cellulose might be less than the actual value. However, some qualitative analysis could be applied compared with Table 4. Table 6 showed that fruit vegetable biomass contained more hemi-cellulose than wood biomass, orange peel contained the largest amount of hemi-cellulose and poplar wood contained the largest amount of cellulose, which was consistent with that of Section 3.3. However, Table 6 showed that wood biomass contained more lignin, while Table 4 showed that the lignin content of Chinese cabbage was extremely high. The reason was that Chinese cabbage contained some other components besides hemicellulose, cellulose and lignin, as elucidated in Section 3.3.

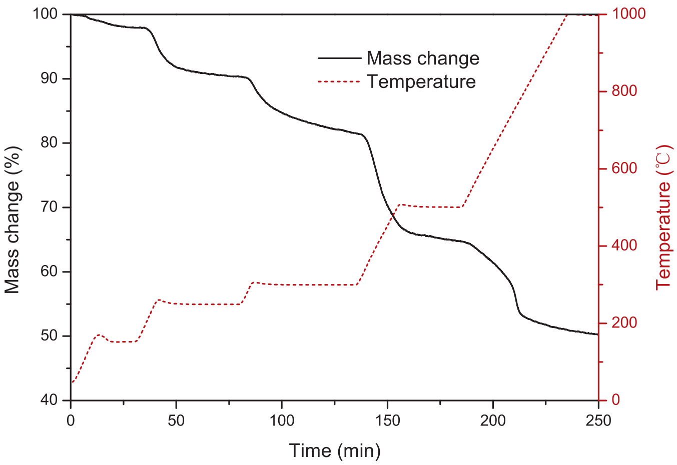

Fig. 11. Fractionated pyrolysis TG curve of lignin (dealkaline).

Table 6
The mass loss of biomass derived from hemi-cellulose, cellulose and lignin.

Biomass	Mass loss derived from hemi-cellulose (%)	Mass loss derived from cellulose (%)	Mass loss derived from lignin (%)
Poplar wood	9.16	16.17	46.08
Poplar leaf	11.12	10.25	43.05
Chinar leaf	8.78	8.07	50.89
Chinese cabbage	14.32	7.85	39.10
Orange peel	23.68	12.26	31.35

4. Conclusions

The thermal behavior of poplar wood, poplar leaf, chinar leaf, Chinese cabbage and orange peel was investigated using TGA, respectively. The pyrolysis process of biomass could be divided into 3 phases. To explore the relationship of biomass and its components, 1 kind of hemi-cellulose, 4 kinds of cellulose and 4 kinds of lignin were also experimented by TGA.

The first mass loss peak of Chinese cabbage and orange peel was close to the first peak of hemi-cellulose, while the first peak of wood biomass was close to the second peak of hemi-cellulose. The hemi-cellulose in fruit vegetable biomass was different from the hemi-cellulose in wood biomass. The cellulose mass loss peak of biomass came close to the peak of cellulose located at 313–354 °C. Because the monomer of cellulose was simplex, the cellulose in different materials presented coincident properties. However, the peak temperature of Chinese cabbage presented lower than that of other materials. The pyrolysis properties of different lignin varied greatly because of different monomers.

The TG curve overlap ratio was applied to evaluate the simulation of biomass by hemi-cellulose, cellulose and lignin. All the biomass could be well simulated with the curve overlap ratios reaching more than 0.9765. The simulation results of poplar wood agreed well with the components derived from chemical method.

The fractionated pyrolysis results showed that fruit vegetable biomass contained more hemi-cellulose than wood biomass and poplar wood contained the largest amount of cellulose, which was consistent with the results based on the overlap ratio. The overlap ratio results showed that the lignin content of Chinese cabbage was extremely high, and the reason was that Chinese cabbage contained some other components besides hemicellulose, cellulose and lignin.

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